

SURVEY OF AVIATION BIRD STRIKE HAZARD AND ITS NUMERICAL SIMULATION

Climent, H., Casillas, T., Martinez, A., Muñoz, C. and Hidalgo, M.*

***h.climentma@gmail.com**

*University Carlos III Madrid, UC3M
Av, de la Universidad,30, 28911, Leganés (Madrid)
Spain*

ABSTRACT

According to FAA, “eighty-one strikes resulted in a destroyed aircraft from 1990-2022 (none in 2022); 46 (57 percent) of these occurred at general aviation airports. The annual cost of wildlife strikes to the USA civil aviation industry in 2022 was projected to be 67,848 hours of aircraft downtime and \$385 million in direct and other monetary losses” [01]. These 81 aircraft lost were only in the US. The probability of a bird strike per flight hour has multiplied by 3 in the last 30 years and the increase trend will continue in the future. Similar aircraft losses and impact trends have been reported in Europe by EASA, in China and also in the available military aircraft databases.

Next sequence of photos show an airshow incident in Spain 15-Jun-2025 in which an Eurofighter canopy was hit by –likely- a seagull. The consequence on the damaged canopy shown in the fourth photo evidences that bird strike is a serious aviation hazard that poses a significant threat to flight safety.



This paper presents a survey of more than 150 references, papers, books and reports, covering the many different aspects of the bird strike problem and analysing the alternatives for its numerical simulation. The authors conclude that by using the explicit Finite Element Method (FEM) technique combined with Smoothed Particle Hydrodynamics (SPH) modelled birds the problem can be simulated today with suitable accuracy at a reasonable cost, although other alternatives and promising new methods will be also presented.

In addition to the references reviewed, the authors present sensitivity analysis and results based on their own simulations and the test data from various sources used for validation of models (bird, material characteristics, specimens, etc). The strain rate effect in tension cases that will be shown in the paper has not been addressed so often in the literature like the compression cases...The final part of the paper will address the stochastic approach needed to properly assess the margin in presence of uncertainties.

In a nutshell, the aspects addressed by the paper will be:

- **Bird strike history and current statistics.**

The paper will show a deep comparison among civil aircraft statistics from different sources: US, Europe and China as well as available military statistics. The trend shows that the increase of bird strike rate per flight hour that has multiplied by 3 in the 1990-2022 period will continue growing in the future.

- **The Airworthiness Regulations**

- Civil
- Military

The paper will address the suitability of current civil regulations [02] in view of the increase of bird strike rate with respect to the time were the regulations were formulated. Military aircraft regulations will be also compared, specially UK DEF-STAN [03] and the most modern US EN-SB-12-002 [04]

- **The numerical simulation approaches to address this problem and the test validations**

Previous surveys and reference papers (like [05]) will be thoroughly reviewed and critically assessed. Among all available options to industry that will be critically compared in the paper, the authors conclude that a combination of explicit FEM technique combined with SPH bird models is today probably the most suitable option combining accuracy and affordability.

- **The bird model**

- Shape, geometry, size
- Number of SPH particles
- Constitutive model (Equation of State EOS)
- Validation data

- **The material characterization of the impacted specimen**

- Metallic
- Composite
- Rivets & Joints
- Transparencies

- Propeller blade composition

Most of the literature addresses the strain rate effect in compression cases that are the typical loading cases for energy absorbing devices, crashworthiness, ditching, etc. Nevertheless, the solicitation in bird strike maybe tension in many cases.

- **The impacted specimen**

- Lifting surface leading edge (wing, empennage).
- Engine intake or nacelle
- Transparencies (observation bubbles in maritime patrol aircraft, pilot windscreens in airliners, windshields or canopies in combat aircraft, etc.)
- Rotating propellers

- **The important parameters affecting the specimen integrity** (i.e. bird kinetic energy per unit of bird impact area)

- **The stochastic technique to cover uncertainties**

The uncertainties inherent in this problem could be addressed by using the stochastic technique in order to obtain a robust margin and the real probability of failure.

- **Conclusions and future developments**

The paper complements previous publications in the field by the authors. As an example, references [06]-[10] is a summary of these publications.

References

[01] FAA NWSD Serial Report 29 “Wildlife Strikes to Civil Aircraft in the United States 1990-2022” (June 2023)

[02] EASA CS-25. European Union Aviation Safety Agency Certification Specification for Large Aeroplanes. Paragraphs: CS-25.631; CS-25.571; CS-25.775; AMC 25-631.

[03] DEF-STAN 00-970. Chapter 4.9 Birdstrike Damage

[04] US Air Force EN-SB-12-002 “Methodology to Establish Bird Strike Design Criteria” (27-June-2012)

[05] Heimbs, Sebastian “Computational methods for bird strike simulation: A review” ELSEVIER Computers and Structures. (9-Sep-2011)

[06] Pérez-Galán, J.L., Strömberg, A.M. and Climent, H. “Stochastic Approach to Bird Strike Numerical Simulation,” Proceedings of the International Forum of Aeroelasticity and Structural Dynamics 2005. Munich. 28 June – 1 July 2005.

[07] Climent, H. “Survey of Fixed-Wing Non Linear Problems and Some Recent Solutions,” Keynote lecture at EuroPAM 2006. 16th European Conference and Exhibition on Digital Simulation for Virtual Engineering, Toulouse, 10-12 October 2006.

[08] Pérez-Galán, J.L, Benitez, L., Oliver, M. and Climent, H. “Survey of Aircraft Structural Dynamics Non-Linear Problems and some Recent Solutions,” CEAS 2009 European Air and Space Conference, Manchester. 26 – 29 October 2009. Also in: The Aeronautical Journal. November 2011 Volume 115 N°1173, pages 653-668

[09] Casillas Gil, Tamara “Impact Simulation of Bird Strike on Semi-spherical Transparencies ” UC3M BSc Thesis (22-Jun-2015)

[10] Climent, H. "Aerospace Impacts Technology. An Industrial Perspective," Keynote Lecture at the Aerospace Structural Impact Dynamics International Conference ASIDIC, Seville (Spain), 17, 18 November 2015.